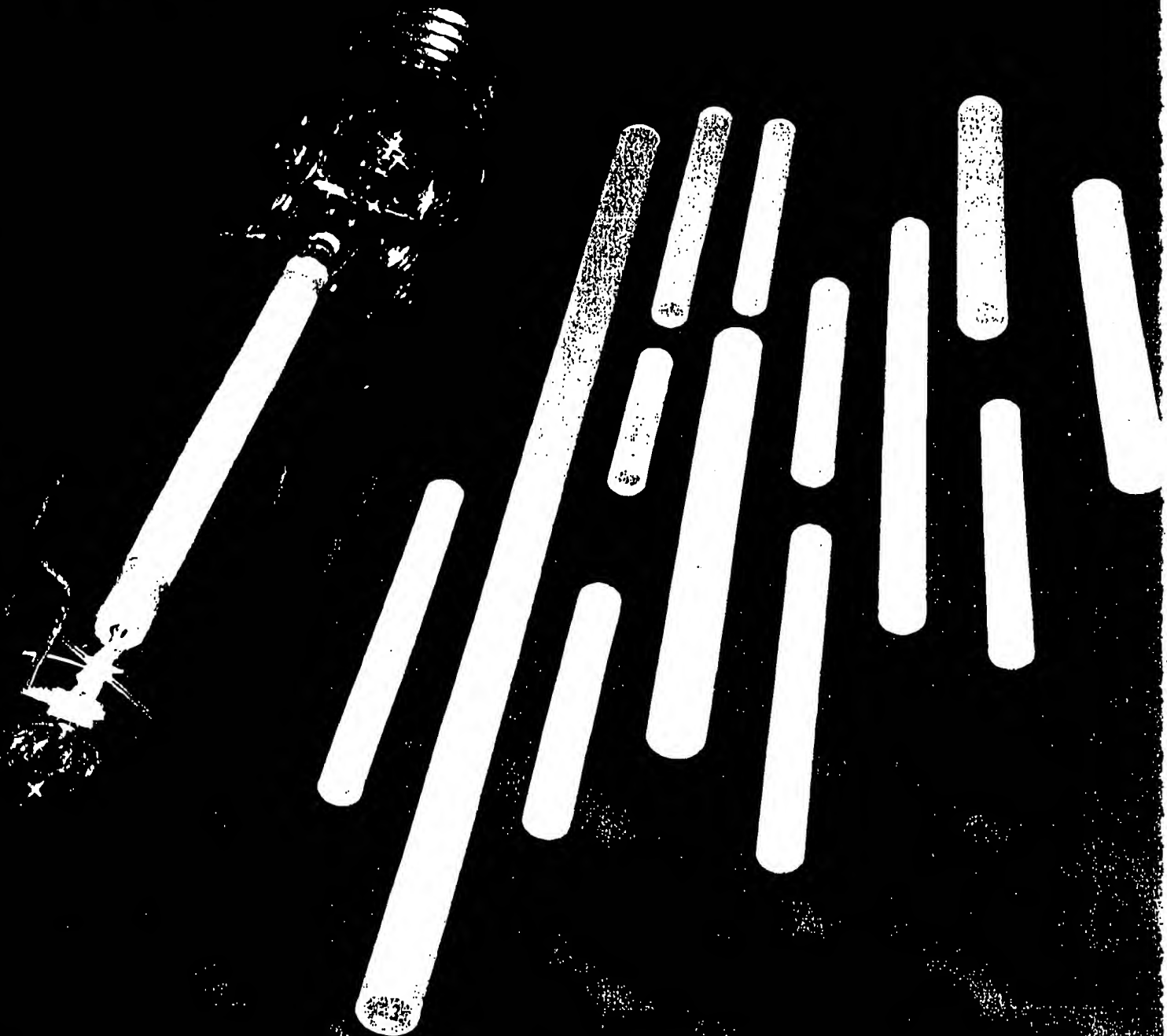


EXHIBIT F



Lucalox[®] Ceramic Tubing



GENERAL  ELECTRIC

GENERAL ELECTRIC COMPANY
Components/Quartz Marketing
and Sales Operation

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Lucalox® Ceramic

Lucalox® ceramic is a polycrystalline translucent aluminum oxide ceramic that demonstrates a remarkable combination of mechanical, electrical and optical properties. A minimum purity of 99.9% aluminum oxide assures highly stable properties. This purity, established through careful controls during the manufacturing of Lucalox ceramic lamp tubes, is very similar to the high purity of sapphire (single crystal alumina). A typical chemical analysis is shown in Table I.

Lucalox ceramic is used primarily for arc tubes in high pressure sodium vapor lamps. It is characterized by a highly translucent appearance and looks very much like frosted glass.

Lucalox ceramic is essentially a single phase material, manufactured by bonding aluminum oxide grains directly to each other. The fine-grain, high purity aluminum oxide is processed at room temperature; then fired at temperatures higher than usual for ceramics. The resulting glass-free struc-

ture provides a high material density and a high temperature stability not found with most conventional ceramics.

Mechanically, Lucalox ceramic is very hard and exhibits both a high compressive strength and a high modulus of rupture. It is capable of withstanding up to 25,000 psi at 1800°C in uniaxial compression.* Table II presents typical physical properties of Lucalox ceramic.

Electrically, Lucalox ceramic demonstrates a high dielectric strength, low dissipation, and low loss factor.

The optical properties of Lucalox ceramic result from its high density, high purity, and controlled grain size. It transmits wave-lengths from the near ultraviolet, through the visible spectrum, and into infrared.

*Armour Research Foundation, ARF Project No. 8203

TABLE I
TYPICAL CHEMICAL ANALYSIS

Trace Element	Si	Fe	Ca	Mg	K	Na	Li	Mo	Cr	Cu
PPM Detected	50	4	7	180	50	80	<1	10	2	4

TABLE II
TYPICAL PHYSICAL PROPERTIES

PROPERTY	LUCALOX® CERAMIC
Microstructure	Polycrystalline
Crystalline Phase	α-Alumina
Purity	99.9% Al ₂ O ₃
Density	≥3.97 gm/cm ³
Porosity	Gas tight (essentially zero)
Average Grain Size	30 microns avg.
Melting Point	2040°C
Color	Translucent White
Hardness-KHN100	2190
Hardness-Rockwell 30N	89
Modulus of Rupture (polished samples)	2.75 x 10 ⁸ Pa
Compressive Strength	2.24 x 10 ⁸ Pa
Young's Modulus	3.93 x 10 ¹¹ Pa
Modulus of Rigidity	1.58 x 10 ¹¹ Pa
Poisson's Ratio	0.23
*Light Transmittance	Exceeds 87% total transmission throughout visible spectrum

*Using integrating sphere method

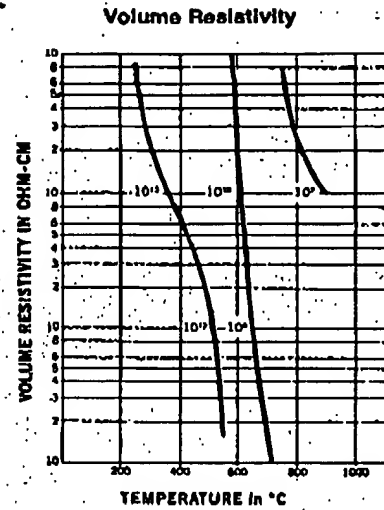
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Electrical Properties

As shown by Table III and the Temperature vs. Resistivity graph, Lucalox ceramic has a high dielectric strength of approximately 1700 volts per mil, plus a high dielectric constant and a high volume resistivity.

TABLE III
ELECTRICAL CHARACTERISTICS

PROPERTY	LUCALOX® CERAMIC
Volume Resistivity	See curve at right.
Dielectric Constant	10.1 (20°C 0.020" at 1 GHz)
Dielectric Strength	1700 volts • mil (20°C 0.020" thick sample—average)
Dissipation Factor	7.5×10^{-4} (20°C at 1 MHz)
Loss Factor	7.6×10^{-3} (20°C at 1 MHz)



Volume resistivity for Lucalox ceramic. Below 240°C, volume resistivity is greater than 8×10^{13} ohm-cm.

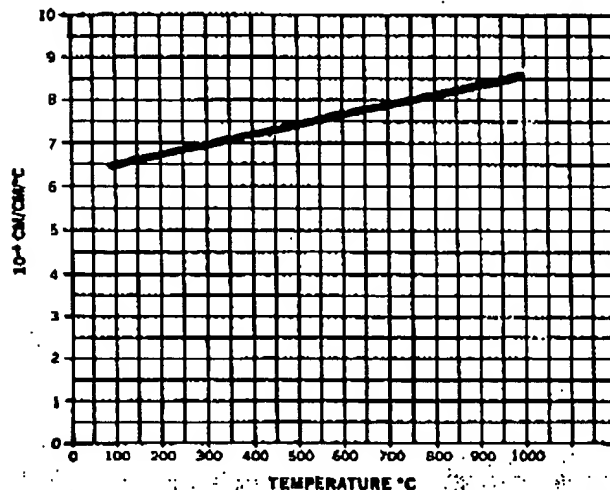
Thermal Properties

Lucalox ceramic has a melting temperature of 2040°C and maintains high strength at temperatures that approach the melting point. The recommended maximum use temperature is 1900°C.

The thermal conductivity of Lucalox ceramic is

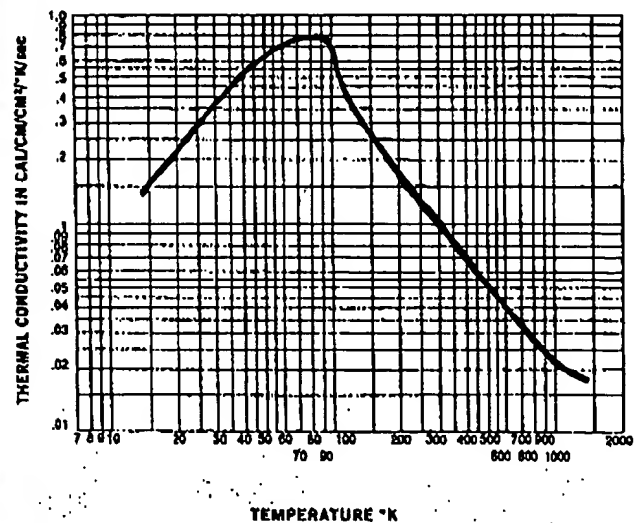
better than some metals, and since Lucalox ceramic is polycrystalline, the expansion is essentially uniform in all directions as shown by the accompanying graph. The thermal shock resistance is very good.

Linear Thermal Expansion Coefficient



Values are from 25°C base temperature.

Thermal Conductivity



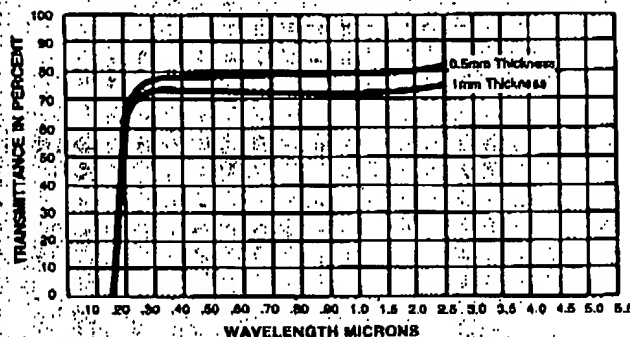
Optical Properties

The total transmittance is strongly dependent on the density and grain size of the Lucalox ceramic. For this reason, the density of Lucalox ceramic is maintained at 3.97 grams/cm³, or greater, and the grain size is controlled to an average of 30 μ .

The following graph presents typical transmittance data for Lucalox ceramic in the visible range. Total transmittance of Lucalox ceramic tubes can exceed 90% throughout the visible region for tubes with .76 mm wall.

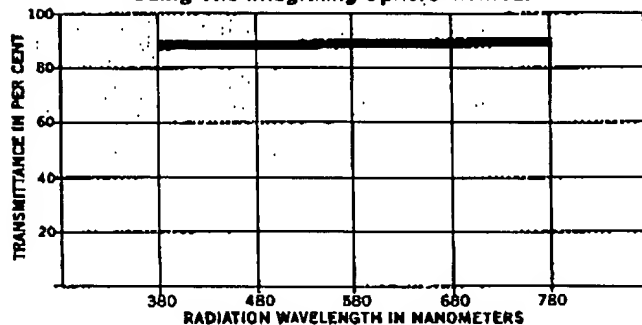
Lucalox ceramic has the appearance of frosted glass and is translucent rather than transparent. Scattering of transmitted light is caused by refraction at the grain boundaries and by crystalline birefringence. There is no infrared absorption due to hydroxyl ion in Lucalox ceramic.

Forward Diffuse Transmittance of Energy Normally Incident on Lucalox® Ceramic Plates*

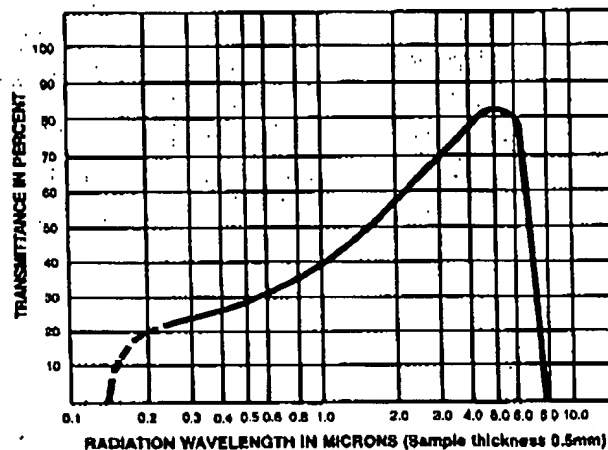


*Total transmittance of Lucalox ceramic tubes can exceed 90% throughout the visible region for tubes with .76 mm wall.

Total Transmittance of Tubes in The Visible Range Using The Integrating Sphere Method.



In-Line Transmittance



Lucalox® Ceramic Index of Refraction

Wavelength Angstroms	Index of Refraction
7065	1.759
6563 "C"	1.761
5893 "D"	1.764
5461	1.766
4861 "F"	1.771
4341 "G"	1.777
4660	1.789

Sealing to Metal

Active metal sealing techniques such as those used for sapphire and conventional ceramics have been used successfully for sealing Lucalox ceramic to metals.

A great deal of scientific literature is available on various sealing techniques which are appropriate to Lucalox ceramic.

Available Tube Sizes

Lucalox ceramic is available in tube form with an OD range of 5mm to 10mm, a 0.5mm to 1mm wall range, and a 25mm to 260mm length range. All tubing can be supplied with ground ends. In sufficient volume, other sizes will be considered upon request.

Tolerances on all dimensions except length are $\pm 0.13\text{mm}$ or 1%, whichever is greater. Length tolerances are:

- Less Than 75 mm ± 0.5 mm
- 75 mm - 260 mm ± 1.0 mm

TABLE IV
LUCALOX® CERAMIC STANDARD TUBING SIZE
TYPICAL DIMENSIONS

DESIGNATION	OD		WALL		LENGTH RANGE	
	Inch	MM	Inch	MM	Inches	MM
LT 5.0	0.197	5.0	0.020	0.51	1 - 5	25.4 - 127.0
LT 6.5	0.256	6.5	0.030	0.76	1 - 6	25.4 - 152.4
LT 7.0	0.276	7.0	0.030	0.76	1 - 6	25.4 - 152.4
LT 8.8	0.347	8.8	0.030	0.76	1 - 10	25.4 - 254.0

Engineering Assistance

Application engineering assistance is available by writing or calling:

General Electric Company
Components/Quartz Marketing
and Sales Operation
24400 Highland Road
Cleveland, Ohio 44143
Phone: (216) 266-2950

NOTE: The data set forth in this general catalog represent typical values generally representative of product produced but are, of course, subject to variation on any particular batch produced.

Ordering

Domestic

Orders can be handled through Components/Quartz Marketing and Sales Operation sales personnel or placed directly with customer service.

General Electric Company
24400 Highland Road
Richmond Heights, Ohio 44143
Phone: (216) 266-2969

International

Headquarters

General Electric Company
Components/Quartz Marketing &
Sales Operation
International Sales
24400 Highland Road
Richmond Heights, Ohio 44143
Telex: 256612 (GEICS UR)
Phone: (216) 266-3295

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General Electric Company
Components/Quartz Marketing and Sales Operation
24400 Highland Road
Richmond Hts., Ohio 44143
(216) 266-2451
Telex: 256612



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